STRUCTURAL CONCRETE

Contents

Clause	Title	Page
NG1701	Concrete-Classification of Mixes	208
NG 1702	Concrete - Ordinary Structural - Constituent Materials	209
NG 1703	Concrete - Special Structural - Constituent Materials	210
NG 1704	Concrete - General Requirements	211
NG 1705	Concrete - Requirements for Designed Mixes	213
NG 1706	Concrete - Production	214
NG 1707	Concrete - Compliance	214
NG 1708	Concrete - Surface Finish	216
NG 1709	Concrete - Surface Impregnation and Coating	217
NG 1710	Concrete - Construction General	219
NG 1711	Concrete - Grouting of Prestressing Tendons	225
NG 1712	Reinforcement - Materials	226
NG 1713	Reinforcement - Bar Schedule Dimensions - Cutting and Bending	226
NG 1714	Reinforcement - Fixing	226
NG 1715	Reinforcement - Surface Condition	227
NG 1716	Reinforcement - Laps and Joints	227
NG 1717	Reinforcement - Welding	228
NG1718	Prestressing Tendons - Materials	229
NG 1719	Prestressing Tendons - Handling and Storage	229
NG 1720	Prestressing Tendons - Surface Condition	229
NG 1721	Prestressing Tendons - Straightness	229
NG 1722	Prestressing Tendons - Cutting	229
NG 1723	Prestressing Tendons - Positioning of Tendons, Sheaths and Duct Formers	229
NG 1724	Prestressing Tendons - Tensioning	230
NG 1725	Prestressing Tendons - Protection and Bond	230
NG 1727	Inspection and Testing of Structures and Components	231
NG	Sample Appendices	235

Structural Concrete

NG 1701 Concrete - Classification of Mixes

General

1 In the Specification the concept of concrete as a single material has been adopted. It is therefore the responsibility of the Engineer to specify in Appendix 17/1 the type of concrete he requires to ensure both the strength and the durability of the finished structure and to incorporate a compiled Appendix 17/1 in the Contract Documents.

Designed Mix

2 The Contractor should be responsible for selecting the mix proportions in accordance with Clause 1705 to achieve the required strength and workability, but the Engineer is responsible for specifying the minimum cement content, maximum water/cement ratio and other properties required to ensure durability in accordance with Clause 1704.

Designed Mix for Ordinary Structural Concrete

3 By the definition given in sub-Clause 1701.2 limitations on the constituent materials are already established and therefore the Engineer need only specify the following:

Designed Mix for Ordinary Structural Concrete	Specification sub-Clause
Class of concrete	1704.1
Minimum cement content	1704.2
Required type and class of cement	1703.1
Maximum water/cement ratio	1704.2

Designed Mix for Special Structural Concrete

4 These concrete mixes include those using admixtures, those using cements other than in sub-Clause 1702.1, lightweight aggregates, heavyweight aggregates, etc. and those specially designed to have a special property or to produce a particular surface finish which may place a restriction on the use of materials from Clause 1702. It is important, thei-efore, to specify the requirements in detail and, where possible, to state the reasons for any special requirements so that the Contractor can more fully appreciate the object of the work.

In appropriate circumstances any of the following information may be included, but great care should be taken to ensure that the requirements specified do not conflict with each other:

Designed Mix for Special Structural Concrete	Specification sub-Clause
Class of concrete	1704.1
Minimum cement content	1704.2
Maximum water/cement ratio	1704.2
Required workability	1707.3
Maximum cement content	1704.3
Required type and class of cement	1703.1
Required source of special type of aggregate	1703.2
Required admixture	1703.4
Air entrainment required	1707.4
Minimum or maximum temperature of fresh concrete	1710.6 or 1710.7
Rate of sampling and testing	1707.2(i)
Other requirements	1707.1 & 1708.2

Requirements for Fresh Concrete

5 Unless specified otherwise the requirements for the concrete in the fresh or plastic state, particularly its workability (see sub-Clause 1707.3), should be proposed by the Contractor for approval by the Engineer. It may be necessary when working in cold or hot weather to control the temperature of fresh concrete (see sub-Clause 1710.6 or 1710.7).

Where the minimum dimension of concrete to be placed at a single time is greater than 600 mm and especially where the cement content is likely to be 400 kg/m^3 or more, measures to reduce the temperature, such as the selection of aggregates with low coefficients of thermal expansion or of a cement type with a slower release of heat of hydration, should be considered. In exceptional cases other measures to reduce the temperature or to remove evolved heat may be necessary.

NG 1702 Concrete - Ordinary Structural - Constituent Materials

Cement

1 Where cements other than those complying with IS 1 or BS 12 are used, account should be taken of their properties and any particular conditions of use.

High alumina cement concrete does not appear in the Specification. Its use should only be considered in the most exceptional circumstances when the effects of conversion are fully taken into account.

The control of the colour of the pulverised-fuel ash using the Lovibond Comparator is only required to ensure a satisfactory colour to the concrete.

The Lovibond 2000 Comparator and disc reference no. 296570 may be obtained from Tintometer Ltd, Waterloo Road, Salisbury, Wiltshire England.

The use of Portland cement blended with pulverised-fuel ash or ground granulated blastfurnace slag may increase concrete durability and resistance to both chloride ingress and sulphate attack. However, care should be taken due to possible delayed strength development and particular attention should be paid to curing in accordance with sub-Clause 1710.5.

Aggregates

2 (i) General. The Engineer may specify or approve, on request, the use of aggregates other than those specified in sub-Clause 1702.3 or 1703.2, including types or gradings not covered by the appropriate Standards, provided that there are satisfactory data on the properties of concrete made with them.

When high strength concrete is required, the source as well as the type of aggregate may need careful selection based on the results of trial mixes.

Where it is known that any property of any aggregate is likely to have an unusual effect on the strength, density, shrinkage, moisture movement, thermal properties, creep, modulus of elasticity or durability of concrete made with it, the Engineer should take account of these factors in the design and workmanship requirements.

Aggregates having a high drying shrinkage, such as some dolerites and whinstones, and gravels containing these rocks produce concrete having a higher drying shrinkage than that normally expected. This can result in deterioration of exposed concrete and excessive deflections of reinforced concrete unless special measures are taken. For further information see BRE Digest 35.

When air cooled blastfurnace aggregate complying with BS 1047 is used, sampling and testing should be carried out at sufficiently frequent intervals to confirm the bulk density.

Despite initial compliance with the minimum density, substantial variation above this minimum can change the characteristics of the concrete mix if the weights of the aggregates are kept constant. If such variations occur, the mix should be adjusted to allow for them. Further advice on this subject can be obtained from the Building Research Establishment.

(ii) Nominal maximum size. The preferred nominal maximum sizes of aggregate are 40 mm and 20 mm, but if a smaller size is necessary it should be either 14 mm or 10 mm.

(iii) The requirement for daily testing of aggregates for chloride content is to provide a knowledge of the variability and to enable compliance with the requirements of Table 17/2 and sub-Clause 1704.6. Where continuous test data provide information for assessing long term variability, lower test frequencies should be adopted. For example, land-won aggregates with a typical chloride content of less than 0.01^ should not require frequent assessment.

NG 1703 Concrete - Special Structural - Constituent Materials

Cement

1 NG 1702.1 also applies.

Aggregates

2 NG 1702.2 also applies to aggregates for special structural concrete. In addition, the moisture content of lightweight aggregates can vary considerably, and values of up to 25% have been recorded. The use of a microwave oven may prove beneficial in quickly establishing the moisture content.

Lightweight aggregates may continue to absorb water from the mix and consideration may have to be given to allowing the addition of water for workability.

It should be noted that the vibration characteristics of lightweight aggregate concrete may need special techniques to ensure good compaction and finishes.

Admixtures

3 (i) General. Admixtures should be specified by type and effect.

Admixtures should never be regarded as replacement for good concreting practice and should never be used indiscriminately.

Many admixtures are highly active chemicals and may impart undesirable as well as desirable properties to the hardened concrete; their suitability should generally be verified by trial mixes. The trial mix should contain cement of the same make and from the same source as that intended to be used for the Permanent Works. If two or more admixtures are thought to be required in any one mix, the manufacturer of each should be consulted. The Engineer should satisfy himself that the admixture is compatible with all the other constituents of the concrete mix and ascertain whether it accelerates or retards the setting time and any loss of workability.

Only in exceptional circumstances, such as hot weather, should retarders be used in structural concrete. Consideration may be given to their use in grouts for prestressing tendons, especially in hot weather (see NG 1711.1).

(ii) Air-entraining agents. Air-entraining agents used to entrain controlled percentages of air in the concrete generally improve its durability and, in particular, its resistance to frost damage.

When a concrete of Grade 40 or lower is subject to freezing when wet and/or subject to the effects of salt used for de-icing, it should contain entrained air.

For special structural concrete containing entrained air, the addition of 1% air content to the mix can reduce the compressive strength of the concrete by approximately 5%, but if the water/cement ratio is reduced to take account of the improved workability, the cement content may be kept constant for up to 5% air entrainment with only marginal loss of strength.

The carbon contained in pulverised-fuel ash and certain pigments can substantially reduce the effectiveness of air-entraining agents. This does not usually create a problem but care may have to be taken when using these materials. In some cases it may be necessary to increase appreciably the amount of agent used. The amount of air entrained in a concrete mix can also be affected by many other factors, among which are:

(a) Type and amount of admixture used.

(b) Consistency of the mix.

(c) Mix proportions.

(d) Type and grading of the aggregate.

(e) The length of time for which the concrete is mixed.

(f) Temperature. In the range 10°C to 30°C an increase of 10°C can reduce the amount of entrained air by about 25%.

(g) The cement type, source, fineness and cement content of the mix.

Recommended average air contents of fresh concrete should be maintained within the limits specified, irrespective of mixing time and temperature (see NG 1707.5).

Entrained air will increase the cohesiveness of fresh concrete and this should be taken into account in the design of the mix and in the placing and compaction of the concrete.

NG 1704 Concrete - General Requirements

General Considerations

1 The minimum requirements for the strength and durability of the concrete in the hardened state should be decided by the Engineer from consideration of BS 5400 : Part 4, and the guidance in NG 1704.2, but if, in addition, a special property or a particular surface finish is required, these minimum requirements may have to be considerably exceeded.

The grade of concrete required depends partly on the particular use and the characteristic strength needed to provide the structure with adequate ultimate strength and partly on the exposure conditions and the cover provided to any reinforcement or tendons (see BS 5400 : Part 4).

Minimum Cement Content and Maximum Water/Cement Ratio

2 The Engineer should state in Appendix 17/1 the minimum cement content required for each concrete mix. One of the main characteristics influencing the durability of any concrete is its ability to absorb water. With strong dense aggregates, a suitably low absorption is achieved by having a sufficiently low water/cement ratio, by ensuring sufficient hydration of the cement through proper curing methods, and by ensuring maximum compaction of the concrete. Therefore for given aggregates, the cement content should be sufficient to provide adequate workability with a low water/cement ratio so that the concrete can be fully compacted with the means available.

Water reducing admixtures complying with sub-Clause 1703.4 can be beneficial in reducing the free water/cement ratio.

Table NG 17/1 gives the minimum cement content required, when using a particular size of aggregate and maximum water/cement ratio to provide acceptable durability under the appropriate conditions of environment. This table applies to concrete made with cements described in sub-Clauses 1702.1 and 1703.1. The cement contents may need to be greater than the minimum values given in Table NG 17/1 when trial mixes (see NG 1705.2) indicate that this is necessary for:

(i) the consistent production of a concrete with a maximum free water/cement ratio not greater than that given for a particular condition; and

(ii) the conditions of placing and compaction.

For information on minimum cement contents and maximum water/cement ratios required for different sizes of aggregate and particular types of cement to provide a concrete having acceptable durability under exposure to a particular degree of sulfate or acid attack, reference should be made to BRE Digest 363.

It should be noted that when referring to BRE Digest 363 the requirements of Table NG 17/1 also apply.

Where protective coatings for concrete are required these may consist of a suitable primer, hot applied tar complying with BS 76, two coats of cut back bitumen complying with BS 3690. or proprietary materials. (See Clause 2004.)

TABLE NG 17/1: Minimum Cement Content (kg/m^3) and Maximum Water/Cement Ratio Required in Concrete to Ensure Durability

		Prestressed Concrete					*Reinforced Concrete*					*Plain Concrete*				
Environment		Nominal maximum size of aggregate (mm) 40	20	14	10	Max free water/ cement ratio	Nominal maximum size of aggregate (mm) 40	20	14	10	Max free water/ cement ratio	Nominal maximum size of aggregate (mm) 40	20	14	10	Max free water/ cement ratio
Concrete surfaces exposed to: (i) abrasive action by sea water (ii) water with a pH 4.5 or less	Extreme	320	350	370	390	0.45	320	350	370	390	0.45	320	350	370	390	0.50
Concrete surfaces directly affected by: (i) de-icing salts (ii) sea water spray	Very Severe	300	325	345	365	0.45	295	325	345	365	0.45	295	325	345	365	0.50
Concrete surfaces exposed to: (i) driving rain (ii) alternate wetting and drying	Severe	300	325	345	365	0.50	295	325	345	365	0.50	270	300	320	340	0.50
Concrete surfaces above ground level and fully sheltered against all of the following: (i) rain (ii) de-icing salts (iii) sea water spray Concrete surfaces permanently saturated by water with a pH greater than 4.5	Moderate	300	325	345	365	0.50	270	300	320	340	0.50	245	275	295	315	0.50

Maximum Cement Content

3 Cement contents in excess of 500 kg/m^3 should not be used unless special consideration has been given in design to the increased creep, risk of ASR, of cracking due to drying shrinkage in thin sections, and higher thermal stresses in thicker sections. For higher grades of lightweight aggregate concrete, cement contents in excess of 500 kg/m' may be used provided that the Engineer is satisfied that the concrete produced is suitable in all respects.

Maximum Sulphate Content

4 Sulphates are present in most cements and in some aggregates; excessive amounts can cause expansion and disruption in the concrete.

Control of Alkali-Silica Reaction

5 (i) The control of Alkali-Silica Reaction is based on the publication "Alkali-Silica Reaction: General Recommendations and Guidance on the Specification of Building and Civil Engineering Works" published jointly in 1991 by the Institution of Engineers of Ireland and the Irish Concrete Society.

(ii) The Contractor is required to select one of two procedures:

6 (ii) is intended for use where the structure is protected by controlling the reactive silica content of the aggregates;

6 (iii) is used when the structure is protected by controlling the alkali content of the concrete constituents.

A further procedure is given in the publication referred to in (i) above, this procedure is not included here because concrete in bridge structures normally requires a minimum cement content of 360 kg per cubic metre which is the maximum permitted in the excluded procedure.

(iii) Further information on the basis for the protection of concrete structures is given in the publication noted in (i) above which also contains an example of the calculation of alkali content for a typical concrete mix.

NG 1705 Concrete - Requirements for Designed Mixes

Evidence of Suitability of Proposed Mix Proportions

1 Evidence should be submitted to the Engineer for each grade of concrete showing that, at the intended workability, the proposed mix proportions and manufacturing method will produce concrete of the required quality.

Mix proportions having the required minimum cement content proposed by the producer of a particular lightweight aggregate as complying with the strength requirements of Grades 15, 20, 25 or 30 may be accepted in lieu of trial mixes where the Engineer is satisfied that the results can be achieved. For higher grades of concrete, trial mixes should be made. Where lightweight concrete is used the maximum permissible wet density should be specified.

Trial Mixes

2 If trial mixes are required to demonstrate that the maximum free water/cement ratio is not exceeded (see NG 1704.2) two batches should be made in a laboratory with cement and surface dry aggregates known to be typical from past records of the suppliers of the material. The proposed mix proportions should not be accepted unless both batches have a free water/cement ratio below the maximum specified value at the proposed degree of workability. For this purpose existing laboratory test reports may be accepted instead of trial mixes only if the Engineer is satisfied that the materials to be used in the structural concrete will be similar to those used in the tests. The workability of a trial mix should be checked by casting a trial panel representing the most congested part of the work (see NG 1708.1).

NG 1706 Concrete - Production

General

1 The Engineer should take advantage of every reasonable opportunity and facility to inspect the materials and the manufacture of concrete and to take any samples or to make any tests. All such inspection, sampling and testing should be carried out with the minimum of interference with the process of manufacture and delivery.

Aggregate

2 Separate fine and coarse aggregates should be used except for Grades 7.5, 10 and 15, where all-in aggregate may be used. For grades of concrete other than 7.5, 10 and 15, the grading of each size of aggregate from each pit, quarry or other source of supply should be determined at least once weekly. The results of such tests should be reported to the Engineer and should be used to check whether the gradings are similar to those of the samples used in the establishment of the mix proportions. The results of routine control tests carried out by the aggregate producer may be acceptable for this purpose.

Batching and Mixing

3 The mixing time should be not less than that used by the manufacturer in assessing the mixer performance. In the case of mixes of low workability or high cement content, this may not ensure maximum strength, and it may be advisable to determine a satisfactory mixing time by comparing the strength of samples mixed for different times.

It is advisable to check the accuracy of the batching plant measuring equipment at intervals not exceeding 1 month.

The water content of each batch of concrete should be adjusted to produce a concrete of the workability established for the trial mix.

Control of Strength of Designed Mixes

4 (i) Adjustments to mix proportions. During production, adjustments of mix proportions will normally be made in order to minimize the variability of strength and to approach more closely the required mean strength. Such adjustments are regarded as part of the proper control of production, but the specified limits of minimum cement content and maximum water/cement ratio should be maintained. Changes in cement content may have to be declared (see NG 1705.1).

NG 1707 Concrete - Compliance

General

1 Provided that the Engineer is satisfied that the materials used are in accordance with Clauses 1702 or 1703 and that correct methods of manufacture (see NG 1706) and practices of handling raw materials and manufactured concrete have been used, the compliance of:

(i) a designed mix for ordinary structural concrete should be judged by the strength of the hardened concrete in comparison with the specified characteristic strength (see NG 1707.2), together with the cement content in comparison with the specified minimum (see NG 1707.3);

(ii) a designed mix for special structural concrete should be judged in a manner similar to (i) above except that, in addition, when it is applicable, compliance with any specified special requirements should be judged by the standards set out in sub-Clauses 3, 4, 5 and 6 of this Clause.

When the Engineer specifies "other requirements" in Appendix 17/1 (e.g. density or modulus of elasticity of concrete), compliance with those requirements should be determined from a detailed description of the method of test and with tolerances that take appropriate account of variability due to sampling, testing and manufacture, which the Engineer should describe in Appendix 17/1.

Strength

2 (i) General. The rate of sampling should be as specified in Table 17/4 of the Specification. Higher rates of sampling and testing may be required at the start of work to establish the level of quality quickly or during periods of production when quality is in doubt; conversely, rates may be reduced when high quality has been established.

For special reinforced concrete, such as end blocks or hinges, the rates of sampling for prestressed concrete may be considered more appropriate.

(ii) Testing. The testing specified in sub-Clause 1707.2 (ii) should be the normal method of testing concrete production. It achieves a good balance between the risk of incorporating concrete that does not meet the strength requirements and the risk of rejecting satisfactory concrete.

(iii) Special testing. This should be called up for single batches of concrete, for limited production runs or where the Engineer requires assurance that the concrete placed in a particular part of the Works is of adequate strength. It should not, however, be applied to every batch as this would be expensive and would provide no better overall assurance than normal testing.

(iv) Non-compliance. When the average strength of four consecutive test results fails to meet the requirements of sub-Clause 1707.2 (ii), the mix proportions of subsequent batches of concrete should be modified to increase the strength.

The action to be taken in respect of the concrete that is represented by the test results that fail to meet the requirements of sub-Clause 1707.2(h) or (iii), should be determined by the Engineer. This may range from qualified acceptance in less severe cases to rejection and removal in the most severe cases. In determining the action to be taken, the Engineer should have due regard to the technical consequences of the kind and degree of non-compliance, and to the economic consequences of alternative remedial measures either to replace the substandard concrete or to ensure the integrity of any structure in which the concrete has been placed.

In estimating the concrete quality and in determining the action to be taken when the tests indicate non-compliance, the Engineer should establish the following wherever possible:

(a) the validity of the test results, and confirmation that specimen sampling and testing have been carried out in accordance with BS 1881;

(b) the mix proportions actually used in the concrete under investigation;

(c) the actual section of the structure represented by the test cubes;

(d) the possible influence of any reduction in concrete quality on the strength and durability of this section of the structure.

The Engineer may wish to carry out additional tests on the hardened concrete in the structure to confirm its integrity or otherwise. These may include non-destructive methods or taking cored samples (see NG 1727).

Cement Content

3 The observation of batching is one way of ensuring that the correct cement content is maintained.

As an alternative, the cement content may be determined from samples representative of any batch of concrete, provided that a suitable testing regime is used to measure the cement content of fresh concrete to an accuracy of ± 5% of the actual value with a confidence of 95%.

Water/Cement Ratio

4 The ability to comply with the maximum free water/cement ratio specified in the Contract, at a suitable level of workability, will have been determined by means of trial mixes. Provided that the constituent materials and mix proportions are not substantially different from those used in the trial mixes, the water/cement ratio may be judged from workability tests.

As an alternative, the water/cement ratio may be determined from samples representative of any batch of concrete, provided that a suitable testing regime (including errors due to sampling) is used to measure the water/cement ratio of fresh concrete to an accuracy of ± 5% of the actual value with a confidence of 95%.

Air Content of Fresh Concrete

5 It should be noted that the method of measuring air content described in BS 1881 is not applicable to concrete made with light-weight aggregate.

Additional Tests on Concrete for Special Purposes

6 Additional cubes may be required for various purposes. These should be made and tested in accordance with BS 1881, but the methods of sampling and the conditions under which the cubes are stored should be varied according to the purpose for which they are required. For determining the cube strength of prestressed concrete before transfer or of concrete in a member before striking formwork or removing cold weather protection, sampling should preferably be at the point of placing, and the cubes should be stored as far as possible under the same conditions as the concrete in the members. The extra cubes should be identified at the time of making and should not be used for the normal quality control or compliance procedures.

NG 1708 Concrete - Surface Finish

General

1 The type of surface finish required depends on the nature of the member, its final position in the structure, and whether or not it is to receive an applied finish. The appropriate finish, which may vary from face to face, should be carefully chosen and clearly specified.

Wherever possible, samples of surfaces of adequate size (preferably incorporating a horizontal and vertical joint and reinforcement representative of heavily congested zones of reinforcement) should be agreed before work commences. All the factors affecting the quality of the surface finish from formwork should be carefully studied. For detailed descriptions of these factors and their interrelationship, attention is directed to the pamphlet 'Recommendations for the production of high quality concrete surfaces', Cement and Concrete Association Technical Advisory Series, 47.019.

Texture, colour and durability are affected by curing (see NG 1710.5). Where appearance is important, curing methods and conditions, including the time of removal of formwork, require careful consideration. Components that are intended to have the same surface finish should receive the same treatment.

Control of Colour

2 Where uniformity of colour is important, all materials should be obtained from single consistent sources. In formwork, the replacement of individual plywood sheets or sections of timber in large panels should be avoided. Colour can be affected by curing.

Release Agents

3 Release agents for formwork should be carefully chosen for the particular conditions they are required to fulfil. Where the surface is to receive an applied finish, care should be taken to ensure the compatibility of the release agent with the finish.

Surface Finishes for Concrete

4 (i) The class of finish should be shown on the Drawings. Class Fl finish should be specified for unexposed formed surfaces and Class F2 finish normally for exposed surfaces. F3 finish is very costly and should only be used for small areas. F4 is appropriate where large areas are required to have a first-class appearance. Classes F6 to F8 are special finishes and must be described in the Contract specification. Although metal parts should never be permanently embedded within the cover depth from the surface of the concrete, internal ties can be used in ways which will not detract from the appearance. For instance, if made coincident with certain types of surface features (e.g. vertical grooves formed to break up large areas or features which create shadow effects) the holes are practically indiscernible and an economical design of formwork ensues. The Engineer is urged to be flexible in his requirements for surface features, bearing such facts in mind. For Class F3, F4, F6, F7 and F8 finishes, it is recommended that trial panels should be made. Class F5 finish is primarily intended for precast pretensioned beams. The position of the exposed surfaces, in the finished structure should be taken into account in determining the extent of making good. In cases where beams are of the same design it is possible, within practical limits, to minimise the extent of making good by selecting beams with the best surface finish for positions of maximum exposure.

There have been some difficulties over what constitutes an acceptable finish in precast prestressed beams. The Engineer is advised to inspect typical beams from a beam manufacturer's works before deciding whether a finish is required which is different from that normally produced. This should be agreed with the Contractor before an order is placed.

(ii) Class U2 finish should normally be specified for exposed concrete; Class U3 being reserved for positions where the surface is required to be especially smooth for functional or aesthetic reasons. The method adopted for finishing a surface which is to receive deck waterproofing should be such that a layer of laitance is not left on the surface nor the coarse aggregate exposed.

(iii) Other classes of finish should be fully specified and scheduled in Appendix 17/3 and should, if possible, be related to samples that are readily available for comparison. Included under this heading is any finish that requires the coarse aggregate to be permanently exposed, the use of special forms or linings, the use of a different concrete mix near the surface, grinding, bush-hammering or other treatment.

Protection

5 High quality surface finishes are susceptible to subsequent damage, and special protection may have to be provided in vulnerable areas.

NG 1709 Surface Impregnation and Coating

General

1 Because of the wide variety of structural types and span arrangements etc., all parts of a structure are not equally liable to attack by chloride and atmospheric attack nor are all parts equally liable to cracking. Generally, the risk depends upon the degree of exposure to de-icing salt, liquid gases and other salts which in turn depends on the environment, the geometry, design and location of individual members. It is highly desirable to treat all exposed reinforced and prestressed concrete surfaces subjected to traffic spray and/or possible leakage from deck joints. The following list of surfaces to be treated is intended as a guide when completing Appendix 17/2.

(a) Piers, columns, crossheads and abutments within 8 metres of the edge of the carriageway subjected to traffic spray.

(b) Piers, columns, crossheads and abutments with a deck joint above but with no provision for positive drainage. The tops of these members should also be treated where possible.

(c) Bearing shelves, ballast walls and deck ends with a deck joint above, where possible.

(d) Structures in marine environments, and columns and soffits over brackish water.

(e) Where possible, concrete parapets and parapet plinths (all inclinations) and those areas not protected with deck waterproofing.

(f) Deck beams and soffits directly over the carriageway.

(g) Parts of wingwalls within 8 metres of the edge of carriageway.

(h) Retaining walls within 8 metres of the edge of carriageway.

(i) Webs and tops of bottom flanges of certain types of precast beams may need to be treated before erection.

All surfaces must be free of contaminants such as curing membranes and all repairs must be carried out before impregnation commences.

Impregnation with Silane or Siloxane

2 Materials currently used for impregnation of concrete structures are either silane or siloxane diluted in suitable solvents. When impregnation is used without coatings it is normal to use silane materials, the use of siloxane materials alone is not recommended. There is a demand for safe and environmentally friendly products with regard to products and solvents used. Impregnation is carried out by saturating concrete surfaces with hydrophobising materials that achieve penetration of the concrete and polycondensate into silicone in the concrete. This produces a water repellant but vapour permeable layer that inhibits the ingress of water and chloride ion. Effectiveness of this layer is determined by the quality of the hydrophobisation, the extent and type of condensation, and the strength and permanence of the bond between the active polycondensated products of the impregnation materials and the substrate.

The depth of penetration will vary depending on concrete quality and other factors. Impregnation is known to be effective for at least 15 years, provided it is applied correctly. Longer service lives are anticipated. However, it is considered advisable until further experience is gained to assume that reapplication will be necessary after about 20 years.

Silane

3 Silane hydrolyses with moisture in the atmosphere. Therefore, the contents of any opened container should be used within 48 hours or discarded.

Equipment for Silane Application

4 The type of equipment used should be in accordance with the manufacturer's instructions.

Surface Condition for Silane Application

5 The Engineer should ensure that necessary repairs are completed and that curing membranes, where they have been used, have fully degraded before impregnation is carried out. If this is not the case, the surface has to be prepared by suitable means.

Application of Silane

6 (i) Isobutyl silane has a temporary softening effect when it comes into contact with elastomeric bearings, painted steel surfaces, and bituminous materials and joint sealants, and these items should be protected during application .

(ii) Depending on chmatic conditions, it may be necessary to protect surfaces to be treated to ensure that they are surface dry before impregnation. In a marine environment impregnation should be carried out at the earliest opportunity after it has been demonstrated that there are no deposits of the curing membrane remaining and after any specified surface preparation has been carried out.

(hi) During application, saturation flooding should give a run-down of approximately 150 mm and treated areas will initially have a "wet look".

Siloxane

7 Siloxane should be stored carefully and used as quickly as possible (4 weeks upper limit) after opening.

Equipment for Siloxane Application

8 The type of equipment used should be in accordance with the manufacturer's instructions.

Surface Condition for Siloxane Application

9 The Engineer should ensure necessary repairs are completed and that curing membranes, where they have been used, have fully degraded before impregnation is carried out. If this is not the case the surface has to be prepared by suitable means.

Application of Siloxane

10 (i) Isobutyl siloxane has a temporary softening effect when it. comes into contact with elastomeric bearings, painted steel surfaces, bituminous materials and joint sealants, and these items should be protected during application .

(ii) Depending on climatic conditions, it may be necessary to protect surfaces to be treated to ensure that they are surface dry before impregnation. In a marine environment impregnation should be carried out at the earliest opportunity after it has been demonstrated that there are no deposits of the curing membrane remaining and after any specified surface preparation has been carried out.

(iii) During application, saturation flooding should give a run-down of approximately 150 mm and treated areas will initially have a "wet look".

Coating

11 Coating systems, preferably based on acrylates or others which meet the requirements, are applied to the concrete surfaces in order to protect the concrete against the effects of aggressive and corrosive substances e.g. liquids, gases and salts. Therefore, coating systems provide a higher protection than impregnation alone and they offer decorative finishes in addition.

In order to be fully effective, a continuous film of the coating system should to be applied to the concrete surfaces. Honeycombs, blow holes and voids should be filled prior to the application of coating systems using a cementitious fine filler.

Coating systems consisting of a primer and two top coats together with impregnation with a hydrophobic material underneath provide maximum protection.

There is a wide variety of structural types and span arrangements, etc., and not all parts of a structure are equally at risk from chloride and other attack nor are they equally liable to cracking. Generally, the risk depends upon the degree of exposure to de-icing salt, liquid gases and other salts which in turn will depend on the environment, the geometry, design and location of individual members. It is highly desirable to treat all exposed reinforced and prestressed concrete surfaces subjected to traffic spray and/or possible leakage from deck joints. The following list of surfaces to be coated is intended as a guide when completing Appendix 17/2:

(a) Piers, columns, crossheads and abutments within 8 metres of the edge of the carriageway subjected to traffic spray.

(b) Piers, columns, crossheads and abutments with a deck joint above but with no provision for positive drainage. The tops of these members should also be treated where possible.

(c) Bearing shelves, ballast walls and deck ends with a deck joint above, where possible.

(d) Structures in marine environments, and columns and soffits over brackish water.

(e) Where possible, concrete parapets and parapet plinths (all inclinations) and those areas not protected with deck water-proofing.

(f) Deck beams and soffits directly over the carriageway.

(g) Parts of wingwalls within 8 metres of the edge of carriageway.

(h) Retaining walls within 8 metres of the edge of carriageway.

(i) Webs and tops of bottom flanges of certain types of precast beams may need to be coated before erection.

Equipment for Coating Application

12 The equipment used should be in accordance with the manufacturer's instructions.

Surface Condition and Repairs prior to Coating Application

13 It is important that all repairs are carried out before impregnation is commenced as the hydrophobic nature of this treatment will prevent bonding of water cured cementitious repair products.

Application of Coating

14 (i) Solvent-containing products have a temporary softening effect when they come in contact with elastomeric bearings, painted steel surfaces, bituminous materials and joint sealants and these items should be protected during application.

(ii) Depending on climatic conditions, it may be necessary to protect surfaces to be treated to ensure that they are surface dry before coating. In a marine environment, coating should be carried out at the earliest opportunity after it has been demonstrated that there are no deposits of the curing membrane remaining and after any specified surface preparation has been carried out.

NG 1710 Concrete - Construction General

Construction Joints

1 The number of construction joints should be kept as few as possible consistent with reasonable precautions against shrinkage and early thermal movement. Concreting should be carried out continuously up to construction joints.

Where it is necessary to introduce construction joints, careful consideration should be given to their exact location, which should be shown on the Drawings. Alternatively, the location of joints should be subject to agreement between the Engineer and the Contractor before any work commences. Construction joints should be at right angles to the general direction of the member and should take due account of shear and other stresses.

The use of retarding agents painted onto the formwork should be discouraged because they tend to migrate into the concrete under the action of vibration.

Concrete should not be allowed to run to a feather edge and vertical joints should be formed against a stop end. The top surface of a layer of concrete should be level and reasonably flat unless design requirements are otherwise. Joint lines should be so arranged that they coincide with features of the finished work.

If a kicker (i.e. a starter stub) is used, it should be at least 70 mm high and carefully constructed. Where possible, the formwork should be designed to facilitate the preparation of the joint surface, as the optimum time for treatment is usually a few hours after placing.

Particular care should be taken in the placing of the new concrete close to the joint. This concrete should be particularly well compacted and a vibrator should be used.

Formwork

2 (i) Design and construction. The Engineer should satisfy himself that all permanent or temporary formwork, including supports, is adequate for the proper construction of the Works.

Before any formwork is constructed, the Engineer should require the Contractor to provide detail drawings including details of external vibrators where these are proposed.

He may subsequently request calculations if he has doubts about the adequacy of the proposals.

Requirements for permanent formwork, for either internal or external use, should be shown on the drawings and/or described in Appendix 17/4; due regard being given to the conditions to which it is likely to be exposed and to its function in the structure. The material selected for external use must be durable, particularly at exposed edges or joints.

(ii) Projecting reinforcement. The Engineer should ensure that special care is taken when formwork is struck to avoid the risk of breaking off the edge of concrete adjacent to any projecting reinforcement.

Transporting, Placing and Compacting

3 The Engineer should receive from the Contractor details of the method of transporting and placing concrete. Concrete should be transported from the mixer to the formwork as rapidly as practicable by methods that will prevent the segregation or loss of any of the ingredients and maintain the required workability. It should be deposited as near as practicable to its final position to avoid rehandling.

All placing and compacting should be carried out under the direct supervision of a competent member of the Contractor's (or manufacturer's) staff. Concrete should normally be placed and compacted soon after mixing, but short delays in placing may be permitted provided that the concrete can still be placed and effectively compacted without the addition of further water.

The depth of lift to be concreted should be proposed by the Contractor for the agreement of the Engineer. A cohesive concrete mix that does not segregate may be allowed to fall freely through up to 2 m height provided that special care is taken to avoid displacement of reinforcement or movement of formwork, and damage to faces of formwork. In massive sections it is necessary to consider the effect of lift height on the temperature rise due to the heat of hydration.

Concrete should be thoroughly compacted by vibration, pressure, shock or other means during the operation of placing to produce a dense mass having the required surface finish when the formwork is removed.

Whenever vibration has to be applied externally, the design of formwork and disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

The mix should be such that there will not be excess water on the top surface on completion of compaction. It may be necessary to reduce the water content of batches at the top of deep lifts to compensate for water gain from the lower levels, but this can be avoided by designing the mix, checking with preliminary trials and accurately controlling the mix proportions throughout the work.

Spillages of concrete onto other parts of the permanent structure, e.g. structural steelwork, should be removed immediately they occur to avoid damage to finishes. When air entrained concrete is used, reference should also be made to NG 1703.3(h).

Striking of Formwork

4 (i) General

The time at which formwork is struck is influenced by the following factors:

(a) concrete strength;

(b) stresses in the concrete at any stage in the construction period, which in the case of precast units includes the stresses induced by disturbance at the casting position and subsequent handling;

(c) curing (see NG 1710.5);

(d) subsequent surface treatment requirements;

(e) presence of re-entrant angles requiring formwork to be removed as soon as possible after concrete has set to avoid shrinkage cracks;

(f) requirements of any deflection profile.

The formwork should be removed slowly, as the sudden removal of wedges is equivalent to a shock load on the partly hardened concrete.

(ii) Striking period for cast in situ concrete.

Field conditions for control cubes may be simulated by temperature-matching curing or other methods. In the absence of control cubes, reference should be made to the specialist literature, e.g. "Formwork Striking Times - Methods of Assessment" prepared by CIRIA (Report No 67) for appropriate guidance.

The periods given in Table 17/5 of the Specification are not intended to apply where accelerated curing or slip forms are used. Where it is not practicable to ascertain the surface temperature of concrete, air temperatures may be used though these are less precise. In cold weather the period should be increased according to the reduced maturity. For example, for soffit formwork it would be appropriate to increase the value by half a day for each day on which the concrete temperature was between 3°C and 7°C, and by a whole day for each day on which the concrete temperature was below 3°C.

When formwork to vertical surfaces such as beam sides, walls and columns is removed in less than 12 hours, care should be exercised to avoid damage to the concrete, especially to arrises and features. The provision of suitable curing methods should immediately follow the removal of the vertical formwork at such early ages, and the concrete should be protected from low or high temperatures by means of suitable insulation (see NG 1710.5).

Curing

5 (i) Curing Methods

The Engineer should receive from the Contractor details of the proposed methods of curing and protecting the concrete. The method of curing and its duration should be such that the concrete will have satisfactory durability and strength and the member will suffer a minimum of distortion, be free from excessive efflorescence and undue cracking. ***To*** achieve these objectives it may be necessary to insulate the concrete so that it is maintained at a suitable temperature, or so that the rates of evaporation of water from the surfaces are kept to appropriate values, or both. Different curing or drying treatments are appropriate to different members and products. Where necessary, special care should be taken to ensure that similar components are cured as far as possible under the same conditions.

Curing usually consists of maintaining the formwork in place and covering the concrete with a material such as polythene sheet or a curing compound or with an absorbent material that is kept damp for a period of time.

Where formwork is struck before curing is complete some other form of protection should be approved by the Engineer in advance.

Where structural members are of considerable depth or bulk or have an unusually high proportion of cement or are precast units subjected to special or accelerated curing methods, the method of curing should be specified in detail. Some special cases are cited as examples in NG 1710.5(iii).

The higher the rate of development of strength in concrete, the greater the need to prevent excessive differences in temperature within the member and too rapid a loss of moisture from the surface. Alternate wetting and drying should be avoided, especially in the form of cold water applied to hot concrete surfaces. In order to avoid surface cracking, cold water should not be applied to relatively massive members immediately after striking the formwork while the concrete is still hot.

(ii) Accelerated curing. Accelerated curing (which includes steam curing) consists of curing the concrete in an artificially controlled environment, in which the humidity and the rate of temperature rise and fall are controlled, to speed up the rate of increase in strength.

(iii) Additional Considerations. The principal reasons and recommendations for curing concrete are given in (i) and (ii) above. The following parts of this sub-Clause are intended to amplify the factors that should be considered. The recommendations are based on the assumption that the concrete temperature during the curing period will not fall below 2°C. Particular precautions to be taken when concreting at low air temperatures are given in NG 1710.6.

(a) Strength of concrete. The effect of admixtures on curing should be considered. The higher the rate of development of strength of the concrete (and hence of heat of hydration of the cement), the more care should be taken during the early period after casting to prevent excessive differences in temperature within the concrete and excessive loss of moisture from the pour.

The rate of gain of strength is also increased if the temperature of the concrete is raised. An approximate guide to the development of strength at different temperatures can be obtained by using the concept of 'maturity', which may be defined as the area under a curve of the concrete temperature (in degrees Celsius) plotted against time (in hours) calculated from a basis of -10°C. Curing by means of damp absorbent materials is likely to cause a lowering of the temperature of the concrete as a result of the evaporation from the material, and in some circumstances the effect can be significant.

The rate of development of strength diminishes as the concrete dries out; hence excessive evaporation of water from all surfaces may need to be prevented.

(b) Distortion and cracking. The concrete should be cured so that internal stresses within the member, whether due to differences in temperature or differences in moisture content within the concrete, are not sufficient to cause distortion or cracking. The disposition of reinforcement will affect the restraint to the strains, and hence it will have an effect on any distortion and cracking.

In assessing the likely temperature variation within the concrete, the following factors apply:

rate of heat evolution (related to rate of development of strength);

size and shape of member;

different insulation values of curing media (e.g. wooden moulds or water spray);

external temperature.

For example, surface cracking may occur as a result of variation in temperatures due to applying a cold water spray to a relatively massive member immediately after stripping the moulds while the concrete is still hot.

In assessing the likely variation in moisture content within the concrete, the rate of evaporation from unprotected concrete will be higher with atmospheric conditions encouraging evaporation (e.g. low relative humidity, high wind speed, concrete surface hotter than the air), especially if the rate of migration of water through the concrete is greater than the rate of evaporation from the surface, e.g. for:

members of high surface/volume ratio;

concrete at early age or lower grade of concrete.

For example, cracking may occur due to varying shrinkage in members with sudden changes in section that affect the surface/volume ratio appreciably; especially if the more massive section is reinforced and the more slender section is not.

Further information can be obtained from CIRIA Report No. 91, "Early-age Thermal Crack Control in Concrete".

If the shrinkage of units after they are built into the structure is likely to lead to undesirable cracking at the ends of the unit, curing aimed at preventing the loss of water from the unit should be continued no longer than is necessary to obtain the desired durability and strength; thereafter the concrete should be given the maximum opportunity to dry out consistent with the limitation of the variation in moisture content as already outlined.

(c) Durability and appearance. As deterioration is most likely to occur as a result of the concrete providing inadequate protection for the reinforcement, or because of frost attacking the surface concrete, all vulnerable surfaces of concrete should be protected against excessive loss of water by evaporation that would result in a weak, porous surface layer.

Where it is important to prevent the formation of efflorescence, especially in cold weather, the atmosphere adjacent to the surface of the concrete should be maintained at a constant relative humidity approaching 100% for the time given in Table 17/6 of the Specification. Concrete should be protected from wetting and drying cycles.

(iv) Curing liquids, compounds and membranes. Before curing liquids, compounds and membranes are accepted for use on surfaces on which waterproofing systems are to be laid they should be shown to be either:

(a) completely removable by natural or mechanical means; or

(b) compatible with the waterproofing systems so that the bond between the concrete surface and the primer for the waterproofing is not impaired. The Engineer when giving agreement may consider submission by the Contractor of results from comparative tests on site or other evidence that the adhesion of the primer to the concrete is not reduced.

It should be noted that proprietary liquid curing membranes may take a long time to disintegrate and may affect the appearance of permanently visible surfaces as well as the bond of any waterproofing layer.

Only film type membranes that fully degrade by exposure to ultra-violet light should be used where concrete surface impregnation is specified, as other curing liquids, compounds or membranes may leave residues which prevent satisfactory application of the treatment. Sufficient interval should be allowed for the film to fully decompose before impregnation commences (see NG 1709.5). lb achieve optimum breakdown of the membrane, the manufacturers recommendations for prior wetting or dampening of the concrete surfaces and the rate of application of the membrane material should be closely followed.

Cold Weather Work

6 (i) General

The Engineer should receive from the Contractor details of the proposed method for raising and maintaining the temperature of the concrete.

Before placing concrete, the formwork, reinforcement, prestressing steel and any surface with which the fresh concrete will be in contact should preferably be at a temperature close to that of the freshly placed concrete. Special care should be taken where small quantities of fresh concrete are placed in contact with larger quantities of previously cast concrete at a lower temperature. Any concrete damaged by frost should be removed from the work.

Concrete temperatures should be measured at the surface at the most unfavourable position.

(ii) Concrete Temperature

The raising of the temperature of the concrete may be achieved in a number of ways including the following:

(a) By heating the mixing water and aggregate. If the water is heated above 60°C, it is advisable to mix the water with the aggregate before adding the cement.

(b) By increasing the cement content of the mix or by using a more rapid hardening cement.

(c) By covering the top face of slabs and beams with adequate insulating material.

(d) By providing wind breaks to protect newly placed concrete from cold winds.

(e) By using a heated enclosure, completely surrounding the freshly placed concrete or using heated formwork panels. In either event care should be taken to prevent excessive evaporation of water from the concrete.

Formwork should be left in place as long as possible to provide thermal insulation; timber formwork provides better insulation than steel. Further guidance on this subject can be obtained from the Cement and Concrete Association Publication No. 45.007 "Winter Concreting".

Hot Weather Work

7 In hot weather, the incidence of cracking and loss of workability may be reduced if measures are taken to cool the constituent materials. Aggregates can be kept cool by protecting them from direct sunlight and by spraying with water, making due allowance for the moisture content of the mix. Water pipes, particularly if long, should preferably be shaded and if possible insulated.

Surface Preparation of Precast Concrete Units

8 Laitance is the dusky milky cement compound which can be removed after the concrete has hardened using a stiff brush.

Handling and Erection of Precast Concrete Units

9 (i) Manufacture off the Site. The Engineer should receive from the Contractor details of the proposed method of manufacture.

The Engineer should show on the Drawings the type of preparation of the surfaces of concrete members which will subsequently receive in situ concrete.

Supervision of workmanship and materials for factory-made concrete units is as important as for Site work and is most satisfactorily carried out by a resident inspector or by making frequent visits during manufacture.

The Engineer should ensure that the Contractor submits test results; these should help to encourage careful manufacture. Where exceptional circumstances prevent proper supervision being exercised, visual inspection and measurement of the completed units can determine some of the important properties. Reference should also be made to NG 1727. To benefit from manufacturer's normal practice, it is recommended that for factory-made pre-tensioned beams, the Engineer should be prepared to accept alternative types and positions of tendons. Where the size and position of the tendons are shown on the Drawings, the words "or equivalent" should be added and the force before transfer and its eccentricity should be given. The Engineer should ensure that the losses from the type of tendons proposed are no greater than those taken into account in the design.

(ii) Storage. Indelible identity, location and orientation marks should be put on the member end where necessary. The Engineer should in all cases specify the points of support during storage, and these should be chosen to prevent unacceptable permanent distortion and lack of fit of the units. In order to minimize the stresses induced, supporting arrangements that permit only small settlements are to be preferred.

The accumulation of trapped water and rubbish in the units should be prevented. The freezing of trapped water can cause severe damage.

Where necessary, precautions should be taken to avoid rust stains from projecting reinforcement and to minimize efflorescence.

(iii) Handling and transport. Precast units should resist, without permanent damage, all stresses induced by handling and transport. The minimum age for handling and transport should be related to the concrete strength, the type of unit and other relevant factors.

The position of lifting and supporting points, the method of lifting, the type of equipment, the minimum age for handling, and transport to be used should be as specified or agreed by the Engineer.

Care should be taken to ensure that lifting details are practicable and can be used safely, and that no damage results from the lifting equipment.

During transport the following additional factors require consideration:

(a) Distortion of the transporting vehicles.

(b) Centrifugal force due to cornering.

(c) Oscillation. A slim member may flex vertically or horizontally sufficiently to cause damage.

(d) The possibility of damage due to chafing.

(iv) Assembly and erection. Where the method of assembly and erection is part of the design, it should be stated in Appendix 17/4.

In order to ensure compliance with sub-Clause 1710.8(iv)(a) of the Specification, it may be advisable to have the camber of precast beams measured at the factory so that they can be placed in the correct order.

The object of preventing lateral movement of precast beams in composite slab bridges is to prevent differential movement between beams, which may occur if the concrete is placed in longitudinal strips. This is particularly important when the beams are supported on flexible bearings.

(v) Forming structural connections. The precast units should be inspected to ensure that the design requirements of the structural connection can be met.

The precast units should be free from irregularities which may cause damaging stress concentrations. When reliance is placed on bond between the precast and in situ concretes, the contact surface of the precast unit should have been suitably prepared. If frictional resistance is assumed to be developed at a bearing, the construction should be such that this assumption can be realized. Particular care should be given to checking the accurate location of reinforcement and any structural steel sections in the ends of precast members, and to introducing any additional reinforcement needed to complete the connection.

(a) Concrete or mortar packing. When joints between units, particularly the horizontal joints between successive vertical lifts, are load-bearing and are to be packed with mortar or concrete, tests should be carried out to prove that the material is suitable for the purpose and that the proposed method of filling results in a solid joint (for bedding mortar see Clause 2601).

(b) Other packing materials. Where epoxy resin bonding agents for segmental deck construction are to be used, the Engineer should prepare additional specification requirements based on the manufacturers recommendations. Reference should also be made to Federation Internationale de la Precontrainte (FIP) publication FIP/9/2, available from the British Cement Association.

The composition and water/cement ratio of the in situ concrete or mortar used in any connection should be as specified by the Engineer.

Care should be taken to ensure that the in situ material is thoroughly compacted.

The manufacturer's recommendations as to the application and methods should be strictly followed.

The Engineer should receive from the Contractor details of the proposed methods for removing levelling devices such as nuts and wedges.

(vi) Protection. The degree and extent of the protection to be provided should be sufficient for the surface finish and profile being protected, bearing in mind its position and importance. This is particularly important in the case of permanently exposed concrete surfaces, especially arises and decorative features. The protection can be provided by timber strips, hessian, etc., but should not be such as will damage, mark or otherwise disfigure the concrete.

Measurement of Precast Concrete

10 Units may be measured at any convenient time but not less than 7 days after casting, provided that the alternative time proposed by the Contractor is supported by calculations to demonstrate the dimensions predicted for 28 ± 2 days.

Tolerances

11 The tolerances given may need to be revised upwards or downwards in particular cases.

NG 1711 Concrete - Grouting of Prestressing Tendons

General

1 The two main objectives when grouting the ducts of post-tensioned concrete members are:

(i) to protect the prestressing tendons; and

(ii) to provide efficient bond between the prestressing tendons and the concrete members so as to meet design requirements, control the spacing of cracks at heavy overload, and increase the ultimate moment of resistance of the member.

These objectives make it important that the whole of the void space within the duct should be filled. The success of this operation is dependent on adequate design and detailing of grouting inlet points and vents, the production of a grout mix having the desired properties, together with efficient equipment for its injection, and careful workmanship and supervision on the Site.

The important properties of a satisfactory grout for the injection of ducts in post-tensioned members are:

(i) good fluidity and low sedimentation or bleeding in the plastic state, and

(ii) durability and density with low shrinkage in the hardened state in order to hond with the steel and the sides of the duct and to provide protection for the prestressing tendons.

The methods to be adopted should be capable of being carried out on the Site reasonably easily and effectively.

Research has demonstrated that adequate detailing and correct location of both grout inlet points and vents are essential for successful grouting. When grouting undulating ducts, care should be taken to avoid 'downhill' legs, even if this necessitates grouting from low-points other than at anchorages etc.

Grouting trials should be required by the Engineer if necessary to ensure that the above objectives are met. Reference should be made to FIP Guide to good practice - 'Grouting of tendons in prestressed concrete' and details of the trials should be described in Appendix 17/4.

Materials

2 (i) High early strength Portland cement may be used but it is not recommended for general use. The cement should be fresh but not hot, should contain no lumps and preferably should be bagged.

(ii) Sand is not recommended for general use but it may be specified for short, large-diameter ducts. The requirements of sub-Clause 1704.6 regarding alkali-silica reaction should be met.

(iii) Admixtures, normally plasticisers or expanding agents, should be used where experience has shown that their use improves the quality of the grout. They should contain no chlorides, nitrates, sulphates or sulphides, and where an expanding agent is used, the free expansion of the grout should not exceed 10%.

Ducts

3 It is important that the whole volume of the duct should be filled with grout. Grout entries to the duct or anchorages should provide a secure grout-tight connection to the grout pump.

Grouting Equipment

4 The mixing equipment should be of a type capable of producing a homogeneous grout by means of high local turbulence while imparting only a slow motion to the body of the grout. If small lumps remain on the sieve, the cement is too old and the mix should not be used. It is not recommended to use the sieve to eliminate lumps from the grout.

Injecting Grout

5 The volume of the spaces to be filled by the injected grout should be compared with the quantity of grout injected.

Grouting During Cold Weather

6 The grout materials may be warmed within the limits recommended for concrete (see NG 1710.6).

NG 1712 Reinforcement - Materials

Characteristic Strength of Reinforcement

1 The characteristic strengths of reinforcement are given in the appropriate Standards.

Bond Classification

2 The Engineer should state in Appendix 17/4 the type of deformed bar required. (See BS 5400 : Part 4.)

NG 1713 Reinforcement - Bar Schedule Dimensions - Cutting and Bending

1 Where the temperature of the steel is below 5°C, special precautions may be necessary such as reducing the speed of bending or, with the Engineer's approval, increasing the radius of bending. If necessary, reinforcement may be warmed to a temperature not exceeding 100°C.

Where it is necessary to bend reinforcement projecting from concrete, the radius of the bend should be not less than that specified in BS 4466, and the concrete should not be damaged.

Where it is necessary to reshape steel previously bent, this should only be done with the Engineer's approval, and each bar should be inspected for signs of fracture.

NG 1714 Reinforcement - Fixing

1 Cover blocks and spacers should be of such materials and designs as will be durable, will not lead to corrosion of the reinforcement, and will not cause spalling of the concrete cover.

Cover and spacer blocks made from cement, sand and fine aggregate should match the mix proportions of the surrounding concrete as far as is practicable with a view to being comparable in strength, durability and appearance. The Concrete Society Report CS 101 "SPACERS" provides standardized methods of achieving the specified nominal cover and gives standard performance requirements and methods of testing spacers and chairs.

Non-structural connections for the positioning of reinforcement should be made with steel wire or tying devices or by welding (see NG 1717). Care should be taken to ensure that projecting ends of ties or clips do not encroach into the concrete cover.

The cover and position of reinforcement should be checked before and during concreting; particular attention being paid to the position of top reinforcement in cantilever sections. The support of reinforcement to achieve the correct location, cover and spacing is the Contractor's responsibility and supports should not be shown on the Drawings and Bar Schedules.

The concrete cover to reinforcement should be confirmed as soon as possible after the removal of formwork, by the use of non-destructive methods of testing (see NG 1727.2(ii)(d)). A record of this survey should be retained by the Engineer for inclusion in the as-built records.

NG 1715 Reinforcement - Surface Condition

Normal handling prior to embedment in the concrete is usually sufficient for the removal of loose rust and scale from reinforcement; otherwise wire-brushing or sand-blasting should be used.

NG 1716 Reinforcement - Laps and Joints

General Requirements

1 Where continuity of reinforcement is required through the connection, the jointing method used should be such that the assumptions made in analysing the structure and critical sections are realized. The following methods may be used to achieve continuity of reinforcement:

(i) lapping bars;

(ii) mechanical joints;

(iii) threaded reinforcing bars;

(iv) welding (see NG 1717).

Such connections should occur, where possible, away from points of high stress and should be staggered. The use of any other jointing method not listed should be confirmed by test evidence.

Lapping of Bars

2 Where straight bars passing through the joint are lapped, the requirements of BS 5400 : Part 4 apply. When reinforcement is grouted into a pocket or recess, an adequate shear key should be provided on the inside of the pocket.

Where continuity over a support is achieved by having dowel bars passing through overlapping loops of reinforcement, which project from each supported member, the bearing stresses inside the loops should be in accordance with BS 5400 : Part 4.

•Jointing of Bars

3 A number of systems are available for jointing reinforcing bars, which are capable of transmitting the tensile and compressive forces in the bar; these are as follows:

(i) swaged couplers;

(ii) tapered threaded bars and couplers;

(iii) upset bar ends with parallel threads and couplers;

(iv) couplers fixed to the bars with studs for transmitting compressive forces only;

(v) sleeves with tapered closers that align the square sawn ends of bars for transmitting compressive forces only.

The performance of mechanical joints should comply with the requirements of BS 5400 : Part 4 and Clause 1716 of the Specification.

The connection should have a characteristic strength at least as great as the characteristic strength of the connected bars and, where alternating loads exist should have an adequate fatigue life.

The stress in compression reinforcement may be transmitted by bearing of the ends of the bars held in concentric contact by a sleeve or other mechanical device. The ends of bars should be square sawn-cut, and the coupling device should ensure that the bars are held concentrically and in contact during fixing of steel and placing of concrete.

The detailed design of the sleeve and the method of manufacture and assembly should be such as to ensure that the ends of the two bars can be accurately aligned into the sleeve. The concrete cover provided for the sleeve should be not less than that specified for normal reinforcement.

Where there is a risk of a threaded connection working loose, e.g. during vibration of in situ concrete, a locking device should be used.

Where there is difficulty in producing a clean thread at the end of a bar, steel normally specified for black bolts (see BS 4190) having a characteristic strength of 430 N/ram^2 should be used.

The structural design of special threaded connections should be based on tensile and fatigue tests. Where tests have shown the strength of the threaded connection to be at least as strong as the parent bar, the strength of the joint may be based on 80% of the specified characteristic strength of the joined bars in tension and on 100% for bars in compression, divided in each case by the appropriate γ_m factor.

NG 1717 Reinforcement - Welding

General

1 Welding should be avoided if possible. Very significant loss in fatigue strength of reinforcement can occur as a result of welding. Location welds (tack welds used for locating bars) pose a particular fatigue risk (see BS 5400 : Part 10 : 1980) and any welding to shear stirrups requires careful assessment.

Welding may only be undertaken where suitable safeguards, supervision and techniques are to be employed. Where it is acceptable in the design and to BS 5400 : Part 4 and Part 10 : 1980; the Engineer should check that where cyclic loading occurs, the Class of weld given in Table 17 of BS 5400 : Part 10 : 1980 has been achieved.

Where, notwithstanding the above, welding is to be used, and the fatigue effects of the welds have been taken into account in the design, it should if possible be carried out under controlled conditions in a factory or workshop. The competence of the operators should be demonstrated prior to, and periodically during, welding operations.

In such circumstances welding may be considered for:

(i) Fixing in position, e.g. by welding between crossing or lapping reinforcement or between bars and other steel members. Metal-arc welding or electric-resistance welding may be used on suitable steels.

(ii) Structural welds involving transfer of load between reinforcement or between bars and other steel members. Butt welds may be carried out by flash butt welding or metal-arc welding.

The manual metal-arc process is used on Site or in fabrication shops for making joints of every configuration. In particular it is the only process available for making tee joints between bars and anchorage plates and lapped joints between bars. It is emphasized that operators should be trained and possess sufficient skill for producing good welded joints. The flash butt welding process is restricted to fabrication shops where it can produce sound butt welds more rapidly than manual metal-arc welding. The resistance welding process for cross bar joints can be used on Site or in fabrication shops, though for work on Site it is more usual to use manual metal-arc welding. Further guidance on metal-arc welding of reinforcing bars is given in BS 7123.

2 Flash butt welding is carried out by clamping the reinforcing steel bars in water-cooled copper shoes which introduce a large current to the bars. The bar faces are moved slowly towards each other and, when in close proximity, arcing or flashing occurs at those parts of the two faces in closest contact. The arcing or flashing results in intense heating of the bars. This flashing period can be extended to further preheat the joint before completing the weld which is performed by forcing the hot faces together, metal being forced from the hot faces during the actual welding stage to form a collar. Advice on the correct combination of flashing, heating, upsetting and annealing should be obtained from the reinforcement manufacturer.

3 Manual metal-arc welding is a form of fusion welding in which heat for welding is obtained from an arc struck between a consumable stick electrode and the joint faces. The stick electrode consists of a metal core and a flux covering, the flux forming a protective shield for the molten metal in the weld pool, protecting it from atmospheric contamination. In addition the flux includes constituents that can slag off some harmful contaminants that may be present in the joint prior to welding.

4 Other methods such as resistance welding may be used for forming butt welds. This is a similar operation to flash butt welding, contact of the bar faces creating intense heat due to electrical resistance at the interface. After a predetermined period, sufficient to heat the bar faces into a plastic state, the current is turned off, the bars faces are pressed together under great pressure and a welded joint made, with less material upset than arises in flash butt welding. It is, however, necessary to have cleaner bar faces for resistance butt welding than for flash butt welding.

Resistance welding is rarely used for butt welding of reinforcing steel bars, but resistance spot welding finds wide application for joining wires and bars in cross weld configurations. Large automatic machines with multiple pairs of electrodes are used for simultaneously welding many wires and smaller diameter bars to form mesh. In addition, portable guns with single pairs of electrodes are used for tack welding bars of smaller diameter.

Should fabricators wish to use other processes, reference should be made to the reinforcement manufacturer for guidelines in developing satisfactory procedures.

NG 1718 Prestressing Tendons - Materials

1 The characteristic strengths of prestressing tendons are given in the appropriate Standards.

NG 1719 Prestressing Tendons - Handling and Storage

1 Protective wrappings for tendons should be chemically neutral, and suitable protection should be provided for the threaded ends of bars.

When prestressing tendons have been stored on Site for a prolonged period, the Engineer should ensure by tests that the quality of the prestressing tendons has not been significantly impaired either by corrosion, stress corrosion, loss of cross-sectional area, or by changes in any other mechanical characteristic.

NG 1720 Prestressing Tendons - Surface Condition

1 AH prestressing tendons and internal and external surfaces of sheaths or ducts should be free from loose mill scale, loose rust, oil, paint, grease, soap or other lubricants, or other harmful matter at the time of incorporation in the structural member. A film of rust is not necessarily harmful and may improve the bond. It may, however, increase the loss due to friction.

Cleaning the tendons may be carried out by wire brushing or by passing them through a pressure box containing carborundum powder. Solvent solutions should not be used for cleaning without the approval of the Engineer.

NG 1721 Prestressing Tendons - Straightness

1 In cases where straight as-drawn wire is not essential, wire in small-diameter coils (corresponding to the diameter of the blocks in the drawing machine) may be used.

NG 1722 Prestressing Tendons - Cutting

1 In post-tensioning systems the heating effect on the tendon due to mechanical cutting should be kept to a minimum to avoid damage to the anchorage or bond of the tendon, and any undesirable metallurgical effects in the tendon steel within the concrete member. Where tendons between beams on long line prestressing beds are to be cut, the yielding of steel in burning imparts less of a shock load to the beam ends than any cold cutting method and is, therefore, to be preferred.

NG 1723 Prestressing Tendons - Positioning of Tendons, Sheaths and Duct Formers

1 The method of supporting and fixing the tendons (or the sheaths or duct formers) in position should be such that they will not be displaced by heavy or prolonged vibration, by pressure of the wet concrete, by workmen or by construction traffic. The means of locating prestressing tendons should not unnecessarily increase the friction when they are being tensioned.

Sheaths and extractable cores should retain their correct cross section and profile and should be handled carefully to avoid damage. Extractable cores should be coated with release agent only with the approval of the Engineer and should not be extracted until the concrete has hardened sufficiently to prevent it being damaged.

Damage can occur during the concreting operation, and if the tendon is to be inserted later, the duct should be dollied during the concreting process to ensure a clear passage for the tendon. Inflatable rubber duct formers are not suitable for this purpose.

Should the profile of any empty duct be in doubt after the concrete has been cast a technique has been developed of drawing a radioactive source through the duct and plotting its path.

NG 1724 Prestressing Tendons - Tensioning

General

1 Tendons may be stressed either by pretensioning or by post-tensioning according to the particular needs of the form of construction. In each system different procedures and types of equipment are used, and these govern the method of tensioning, the form of anchorage and, in post-tensioning, the protection of the tendons.

Safety Precautions

2 A tendon when tensioned contains a considerable amount of stored energy which, in the event of any failure of tendon, anchorage or jack, may be released violently. All possible precautions should be taken during and after tensioning to safeguard persons from injury, and equipment from damage, that may be caused by the sudden release of this energy. Guidance on the precautions which should be taken is given in Appendix C to BS 5400 : Part 8 :1978.

Pretensioning

3 The transfer of stress should take place slowly to avoid shock that would adversely affect the transmission length.

Post-tensioning

4 (i) Arrangement of tendons. Tendons, whether in anchorage systems or elsewhere should be so arranged that they do not pass around sharp bends or corners likely to provoke rupture when the tendons are under stress.

(ii) Anchorage system. The anchorage system in general comprises the anchorage itself and the arrangement of tendons and reinforcement designed to act with the anchorage. The form of anchorage system should facilitate the even distribution of stress in the concrete at the end of the member, and should be capable of maintaining the prestressing force under sustained and fluctuating load and under the effect of shock.

Provision should be made for the protection of the anchorage against corrosion.

(iii) Tensioning procedure. The measured tendon force should be compared with that calculated from the extension, using the E value for the tendon obtained by measuring the load-extension relationship in a calibrated testing machine with an extensometer of 1 m gauge length. This provides a check on the accuracy of the assumption made for the frictional losses at the design stage; if the difference is significant, corrective action should be taken.

Where a large number of tendons or tendon elements are being tensioned and the full force cannot be achieved in an element because of breakage, slip or blockage of a duct, and if the replacement of that element is not practicable, the Engineer should consider whether a modification in the stress levels can still comply with the design requirements.

The Engineer should specify the order of loading and the magnitude of the load for each tendon.

NG 1725 Prestressing Tendons - Protection and Bond

General

1 It is essential to protect prestressing tendons from both mechanical damage and corrosion. Protection may also be required against fire damage.

It may also be an important design requirement for the stressed tendon to be bonded to the structure.

Protection and Bond of Internal Tendons

2 Internal tendons may be protected and bonded to the member by cement grout in accordance with Clause 1711. Alternatively, the tendons may be protected by other materials such as bitumen or petroleum-based compounds, epoxy resins, plastics and the like, provided that bond is not important.

Protection and Bond of External Tendons

3 A tendon is considered external when, after stressing and incorporation in the work but before protection, it is outside the concrete section. It does not apply, for example, to a slab comprising a series of precast beams themselves stressed with external tendons and subsequently concreted or grouted in so that the prestressing tendons are finally contained in that filling with adequate cover.

Protection of external prestressing tendons against mechanical damage and corrosion from the atmosphere or other aspects of the environment, should generally be provided by an encasement of dense concrete or dense mortar of adequate thickness. It may also be provided by other materials hard enough and stable enough in the particular environment. In determining the type and quality of the material to be used for the encasement, full consideration should be given to the differential movement between the structure and the applied protection that arises from changes of load and stress, creep, relaxation, drying shrinkage, humidity and temperature. If the applied protection is dense concrete or mortar and investigations show the possibility of undesirable cracking, then a primary corrosion protection should be used that will be unimpaired by differential movement.

If it is required that external prestressing tendons be bonded to the structure, this should be achieved by suitable reinforcement of the concrete encasement to the structure.

NG 1727 Inspection and Testing of Structures and Components

General

1 This Clause indicates methods for inspecting and, where necessary, testing whole structures, finished parts of a structure, or structural components to ensure that they have the required standards of finish, dimensional accuracy, serviceability and strength. Where inspection or results of other tests (see NG 1727.2) lead to doubt regarding the adequacy of the structure, loading tests may be made following the procedure set out in NG 1727.6.

In this Clause, deflection means the maximum amount of movement under load of the component being tested, relative to a straight line connecting its points of support. The load tests described in this Clause may not be suitable for:

(i) model testing when used as a basis of design;

(ii) development testing of prototype structures;

(iii) testing to prove the adequacy of a structure, owing to change of use or loading.

Where the Contractor or manufacturer uses a quality control method, and maintains records of the entire process of manufacture (subject to these records being certified by a chartered engineer or a person who has a recognised equivalent qualification of another Member State of the European Communities, and being made available to the Engineer) which show that the products meet the requirements of the Specification, such records may be accepted as confirming that the required quality has been reached. This in no way precludes the Engineer's specifying such tests as he requires.

Testing requirements should be fully described in Appendix 17/4 and scheduled in Appendix 1/5.

Check Tests on Structural Concrete

2 (i) General. The testing of concrete specimens to establish whether the concrete used in the structure complies with the Specification as a structural material is described in Clause 1707 and the additional cube tests for special purposes are dealt with in NG 1707.6. The tests described in sub-Clause (ii) below are applicable to hardened concrete in the finished parts of a structure or in precast units. They may be used in routine inspection and for quality control. They are also of use when concrete is found defective from visual inspection and when low cube strengths are obtained when assessing the strength of the concrete used.

If the results of these check tests show that the quality of the concrete is inadequate or shows other defects, the Contractor may propose that a loading test be made. This should then be carried out in accordance with NG 1727.6.

(ii) Types of check tests

(a) Cutting cores. In suitable circumstances the compressive strength of the concrete in the structure may be assessed by drilling and testing cores from the concrete. The procedure used should comply with BS 1881 : Part 201. Such cores may also be cut to investigate the presence of voids in the compacted concrete. Core cutting should, whenever possible, avoid reinforcement.

(b) Gamma radiography. Gamma radiography may be used to test concrete up to 450 mm thick for the presence of local voids in the concrete and the efficiency of the grouting of ducts in prestressed members; the presence and location of embedded metal may also be determined. The testing should be carried out in accordance with the recommendations in BS 1881 : Part 205. Special precautions are necessary to avoid contamination from the radioactive source.

(c) Ultrasonic test. If an ultrasonic apparatus is regularly used by trained personnel and if continuously maintained individual charts are kept that show, for a large number of readings, the relation between the readings and the strength of cubes made from the same batch of concrete, such charts may be used to obtain approximate indications of the strength of the concrete in the structure.

In cases of suspected lack of compaction or low cube strengths, ultrasonic tests carried out on adjacent suspect and acceptable sections of the structure may provide useful comparative data.

(d) Electromagnetic cover measuring devices. The position of reinforcement or tendons may be verified to depths of about 70 mm by an electromagnetic cover measuring device as described in BS 1881 : Part 204.

(e) Rebound hammer test. If a rebound hammer is regularly used by trained personnel and if continuously maintained individual charts are kept that show, for a large number of readings, the relation between the readings and the strength of cubes made from the same batch of concrete, such charts may be used in conjunction with hammer readings to obtain an approximate indication of the strength of the concrete in a structure or element. An accuracy of ± 3 N/mm^2 could be expected when used by trained personnel in these ch-cumstances.

When making rebound hammer tests, each result should be the average of at least nine individual readings. Readings should not be taken within 25 mm of the edge of concrete members. It may be necessary to distinguish between readings taken on a trowelled face and those taken on a moulded face. When making the test on precast units, special care should be taken to bed them firmly against the impact of the hammer.

Surface Finish

3 The surface of the concrete should be inspected for defects, for conformity with the Specification and, where appropriate, for comparison with approved sample finishes.

Subject to the strength and durability of the concrete being unimpaired, the making good of surface defects may be permitted, but the standard of acceptance should be appropriate to the Class and quality of the finish specified and should ensure satisfactory performance and durability. On permanently exposed surfaces, great care is essential in selecting the mix proportions to ensure that the final colour of the faced area blends with the parent concrete in the finished structure.

Dimensional Accuracy

4 The methods of measurement of dimensional accuracy, making allowance for specified tolerances, if any, should be agreed in advance of manufacture.

The effect of temperature, shrinkage and imposed load should be taken into account.

The positions of bars, tendons or ducts should be checked where these are visible or ascertainable by simple means.

In the case of precast units, the checking of twist, bow, squareness and flatness may entail removal of the unit from its stacked position to a special measuring frame. Extensive checking of units in this manner may materially affect the cost. The frequency and scope of measurement checks should therefore be strictly related to the production method, the standard of quality control at the place of casting, and the function that the unit has to fulfil.

When checking the camber or upward deflection due to prestress, the precast unit should be placed on proper bearings at full span and a central reference point should be provided level with the bearings. The amount of upward deflection to be expected at any stage should be assessed as described in BS 5400 : Part 4. Alternative methods of checking include the use of dial gauges or measurements from a thin wire stretched across the bearings and tensioned sufficiently to take out the sag. Upward deflection is preferably measured on the underside.

(v) Load testing of pretensioned beams. Load testing is not normally required and should only be embarked upon when the adequacy of the beams is in serious doubt.

Load Tests on Individual Precast Units

5 (i) General. The load tests described in this Clause are intended as checks on the quality of the units and should not be used as a substitute for normal design procedures. Where members require special testing, such special testing procedures should be described in Appendix 17/4 and scheduled in Appendix 1/5.

Test loads should be applied and removed incrementally.

(ii) Non-destructive test. The unit should be supported at its designed points of support and loaded for 5 minutes with a load equivalent to the sum of the nominal dead load plus 1.25 times the nominal imposed load. The deflection should then be recorded. The maximum deflection measured after application of the load should be in accordance with requirements defined by the Engineer. The recovery should be measured 5 minutes after the removal of the applied load and the load then reimposed. The percentage recovery after the second loading should be not less than that after the first loading nor less than 90% of the deflection recorded during the second loading. At no time during the test should the unit show any sign of weakness or faulty construction as defined by the Engineer in the light of a reasonable interpretation of relevant data.

(iii) Destructive test. The unit should be loaded while supported at its design points of support and should not fail at its ultimate design load within 15 minutes of the time when the test load becomes operative. A deflection exceeding one-fortieth of the span is regarded as failure of the unit.

(iv) Special test. For very large units or units not readily amenable to tests (such as columns, the precast parts of composite beams, and members designed for continuity or fixity) the testing arrangements should be agreed before such units are cast.

Load Tests of Structures or Parts of Structures

6 (i) General. The tests described in this Clause are intended as a check on structures other than those covered by NG 1727.5 where there is doubt regarding serviceability or strength.

Test loads should be applied and removed incrementally.

(ii) Age at test. The test should be carried out as soon as possible after the expiry of 28 days from the time of placing the concrete. When the test is for a reason other than the quality of the concrete in the structure being in doubt, the test may be carried out earlier provided that the concrete has already reached its specified characteristic strength.

When testing prestressed concrete, allowance should be made for the effect of prestress at the time of testing being above its final value.

(iii) Test loads. The test loads to be applied for deflection and local damage are the appropriate design loads, i.e. the nominal dead and imposed loads. When the ultimate limit state is being considered, the test load should be equivalent to the sum of the nominal dead load plus 1.25 times the nominal imposed load and should be maintained for a period of 24 hours. If any of the final dead load is not in position on the structure, compensating loads should be added as necessary.

During the tests, struts and bracing strong enough to support the whole load should be placed in position, leaving a gap under the members to be tested, and adequate precautions should be taken to safeguard persons in the vicinity of the structure.

(iv) Measurements during the tests. Measurements of deflection and crack width should be taken immediately after the application of load and, in the case of the 24-hour sustained load test, at the end of the 24-hour loading period, after removal of the load and after the 24-hour recovery period. Sufficient measurements should be taken to enable side effects to be taken into account. Temperature and weather conditions should be recorded during the test.

(v) Assessment of results. In assessing the serviceability of a structure or part of a structure following a loading test, the possible effects of variation in temperature and humidity during the period of the test should be considered.

The following recommendations should be met:

(a) For reinforced concrete structures the maximum width of any crack measured immediately on application of the test load for local damage should not be more than two thirds of the value for the serviceability limit state of cracking given in BS 5400 : Part 4. For prestressed concrete structures or elements considered under Class 1 or Class 2, no visible cracks should occur under the test load for local damage.

(b) For members spanning between two supports, the deflection measured immediately after application of the test load for deflection should be not more than the specified value. Limits should be agreed before testing cantilevered portions of structures.

(c) If, within 24 hours of the removal of the test load for the ultimate limit state as calculated in NG 1727.6(iii), a reinforced concrete structure does not show a recovery of at least 75% of the maximum deflection shown during the 24 hours under load, the loading should be repeated. The structure should be considered to have failed to pass the test if the recovery after the second loading is not at least 75% of the maximum deflection shown during the second loading.

fd) If, within 24 hours of the removal of the test load for the ultimate limit state as calculated in NG 1727.6(iii), a prestressed concrete structure or member, considered under Class 1 or Class 2 does not show a recovery of at least 85% of the maximum deflection shown during the 24 hours under load, the loading should be repeated. The structure or member should be considered to have failed to pass the test if the recovery after the second loading is not at least 85% of the maximum deflection shown during the second loading.

NG SAMPLE APPENDLX 17/1: CONCRETE - CLASSIFICATION OF MIXES

	Mix Reference		
^Ordinary or Special Concrete (0 or S)			
*Class of Concrete (Grade/Max. Agg. Size)			
* Minimum Cement Content (kg/m^{1})			
^Maximum Free Water/Cement Ratio			
Required Workability			
Max. Cement Content (kg/m^{3}) [See NG 1704.3]			
* Required Type and Class of Cement			
Required Source/Special Type of Aggregate			
Required Admixture			
Air Entrainment Required IYES/N01			
Min. or Max. Temp, of Fresh Concrete °C			
Sampling and Testing	t	t	i
Other Requirements			

*[Notes to compiler: For ordinary structural concrete only information indicated by * need be specified.*
In appropriate circumstances any of the above information may be included, but great care should be taken to ensure that the requirements specified do not conflict with each other.

f Cross-reference should be made to Appendix 1/5 or 116 as appropriate.]

NG SAMPLE APPENDIX 17/2: CONCRETE - IMPREGNATION AND COATING SCHEDULE

[Notes to compiler: State if impregnation materials are to be based on Silane or Siloxane (see 1709.2). Areas to be impregnated and areas to be coated should be scheduled. If considered preferable the schedule can be placed on a Drawing and this Appendix should cross-refer.]

NG SAMPLE APPENDIX 17/3: CONCRETE - SURFACE FINISHES

fNote to compiler: Include here:]

1 Requirements for Contract-specific surface finishes *[1708.4] [cross-referring to the Drawings as appropriate.]*

2 Requirements for trial panels *[1708.1]*.

3 Positions where internal ties are permitted (other than in rebates) for Class F4 finish *[1708.4(i)]*.

4 Locations where a regular pattern of formwork joints is unnecessary *[1708.4(i)J*.

NG SAMPLE APPENDIX 17/4 : CONCRETE - GENERAL

[Note to compiler: This should include:]

1 Requirements for concrete if different from the requirements of sub-Clause 1701.1.

2 Requirements for lightweight aggregate if different from the requirements of sub-Clause 1703.2.

3 Requirements for admixtures if different from the requirements of sub-Clause 1703.4(i).

4 Requirements for sampling and testing if different from the requirements of sub-Clause 1707.1. Whether special testing is required *[1702.2(iiij]. [Cross-reference should be made in Appendix 1/5 or 1/6 as appropriate].*

5 References to drawings which show lifting and support points */1710.8(H) and (iii)].*

6 Whether grouting trials are required, and details of the trials */1711.1].*

7 Locations requiring stainless steel wire other than those described in sub-Clause 1714. l(ii).

8 Requirements for tolerance if different from the requirements of sub-Clause 1710.8, 1710.9 and 1723.1.

9 Requirements for time of stressing if different from the requirements of sub-Clauses 1723.4 and 1724.4.

10 Requirements for protection of prestressing tendons *[1725.1].*

11 Requirements for inspection and testing of structures and components *[1727.1]. [Guidance is given in NG 1727. Tests should be scheduled in Appendix 115].*

12 Requirements for permanent formwork *[1710.2(iv)J.*

13 Requirements for assembly and erection of precast concrete members *[1710.8(iv)j.*

14 Whether type 1 or type 2 deformed bars are required *[1712.4].*